

CLAIMS

We Claim:

- 1 1. A method for preparing crosslinked particles, comprising:
 - 2 (a) providing synthetic polymer molecules having a plurality of
 - 3 crosslinkable groups that are inert until activated, but which when activated
 - 4 undergo an irreversible intramolecular crosslinking reaction; and
 - 5 (b) activating the crosslinkable groups under crosslinking conditions,
 - 6 whereby irreversible intramolecular crosslinking of the polymer molecules occurs
 - 7 to form crosslinked particles.
- 1 2. The method of Claim 1 wherein the crosslinked particles are inert under said
- 2 crosslinking conditions with respect to intermolecular crosslinking with said
- 3 polymer molecules.
- 1 3. The method of Claim 1 wherein the crosslinked particles are inert under said
- 2 crosslinking conditions with respect to intermolecular crosslinking with each
- 3 other.
- 1 4. The method of Claim 1 wherein the polymer molecules are added to a solvent
- 2 prior to activation of the crosslinkable groups to form a polymer molecule
- 3 solution, such that the crosslinkable groups are activated in the solvent and the
- 4 crosslinked particles are formed therein.
- 1 5. The method of Claim 4 wherein (b) is carried out by slowly adding a coupling
- 2 agent to the polymer molecule solution so as to promote intramolecular
- 3 crosslinking.
- 1 6. The method of Claim 1 wherein the crosslinkable groups are thermally activatable,
- 2 and (b) is carried out by heating the polymer molecule.
- 1 7. The method of Claim 6 wherein (b) is carried out by adding the polymer
- 2 molecules to a solvent maintained at a temperature sufficiently high to activate the
- 3 crosslinkable groups.
- 1 8. The method of Claim 1 wherein the crosslinkable groups are photolytically
- 2 activatable, and (b) is carried out by irradiating the polymer molecule.

- 1 9. The method of Claim 1 wherein the crosslinkable groups are activatable with
2 ultraviolet radiation, ionizing radiation, or electron beam radiation.
- 1 10. The method of Claim 9 wherein (b) is carried out by slowly adding the polymer
2 molecules to an irradiated solvent so as to promote intramolecular crosslinking.
- 1 11. The method of Claim 1 wherein the crosslinkable groups are activatable by a
2 chemical activating agent, and (b) is carried out by contacting the polymer
3 molecules with the chemical activating agent.
- 1 12. The method of Claim 11 wherein (b) is carried out by slowly adding the chemical
2 activating agent to the polymer molecules so as to facilitate intramolecular
3 crosslinking.
- 1 13. The method of Claim 11 wherein (b) is carried out by slowly adding the polymer
2 molecules to the chemical activating agent so as to facilitate intramolecular
3 crosslinking.
- 1 14. The method of Claim 11 wherein the chemical activating agent is selected from
2 the group consisting of free radical initiators, acids, bases, organic catalysts,
3 organometallic catalysts, metallic catalysts, nucleophiles and electrophiles.
- 1 15. The method of Claim 1 wherein the molecular weight of the polymer molecules is
2 selected to provide crosslinked particles approximately 2 nm to 100 nm in
3 diameter.
- 1 16. The method of Claim 15 wherein the molecular weight of the polymer molecules
2 is selected to provide crosslinked particles approximately 2 nm to 25 nm in
3 diameter.
- 1 17. The method of Claim 16 wherein the molecular weight of the polymer molecules
2 is selected to provide crosslinked particles approximately 2 nm to 10 nm in
3 diameter.
- 1 18. The method of Claim 1 wherein the number of crosslinkable groups on the
2 polymer molecules is selected to provide a crosslinked particle approximately 2
3 nm to 100 nm in diameter.
- 1 19. The method of Claim 18 wherein the number of crosslinkable groups on the

- 2 polymer molecules is selected to provide a crosslinked particle approximately 2
3 nm to 25 nm in diameter.
- 1 20. The method of Claim 19 wherein the number of crosslinkable groups on the
2 polymer molecules is selected to provide a crosslinked particle approximately 2
3 nm to 10 nm in diameter.
- 1 21. The method of Claim 1 wherein the crosslinking density on the polymer
2 molecules is selected to provide a crosslinked particle approximately 2 nm to 100
3 nm in diameter.
- 1 22. The method of Claim 21 wherein the crosslinking density on the polymer
2 molecules is selected to provide a crosslinked particle approximately 2 nm to 25
3 nm in diameter.
- 1 23. The method of Claim 22 wherein the crosslinking density on the polymer
2 molecules is selected to provide a crosslinked particle approximately 2 nm to 10
3 nm in diameter.
- 1 24. The method of Claim 4 wherein the polymer molecules and the crosslinkable
2 groups thereon are selected so that the hydrodynamic volume of the crosslinked
3 particles in the solvent is up to about 80% less than the hydrodynamic volume of
4 the polymer molecules prior to crosslinking.
- 1 25. The method of Claim 24 wherein the hydrodynamic volume is about 5-60% less
2 than the hydrodynamic volume of the polymer molecules prior to crosslinking.
- 1 26. The method of Claim 25 wherein the hydrodynamic volume is about 35-50% less
2 than the hydrodynamic volume of the polymer molecules prior to crosslinking.
- 1 27. The method of Claim 25 wherein the hydrodynamic volume is about 5-30% less
2 than the hydrodynamic volume of the polymer molecules prior to crosslinking.
- 1 28. The method of Claim 1 wherein the polymer molecules are linear.
- 1 29. The method of Claim 1 wherein the polymer molecules are branched.
- 1 30. The method of Claim 29 wherein the polymer molecules are star polymers,
2 hyperbranched polymers, graft polymers or dendritic polymers.
- 1 31. The method of Claim 1 wherein the polymer molecules are block copolymers and

- 2 the crosslinkable groups are contained in at least one block of the polymer
3 molecule.
- 1 32. The method of Claim 1 wherein the polymer molecules have a backbone
2 comprised of monomer units selected from the group consisting of ethylenically
3 unsaturated polymerizable monomers, nitrogenous polymers, olefins,
4 condensation monomers, ring-opening monomers, esters, sulfones, lactides,
5 lactones, carbonates, imides, arylenes, amides, propylene, ethers, urethanes, vinyl
6 and vinyl derivatives, and organic polysilicas.
- 1 33. The method of Claim 32 wherein each crosslinkable group is directly bound to a
2 monomer unit.
- 1 34. The method of Claim 32 wherein each crosslinkable group is indirectly bound to a
2 monomer unit through a linking group.
- 1 35. The method of Claim 1 wherein the crosslinkable groups are selected from the
2 group consisting of acryloyl, lower alkyl-substituted acryloyl, vinyl, substituted
3 vinyl, cyclic ether, cyclic ester, activated ester, cycloalkenyl, acid halide, amino,
4 alcohol, phenol, carboxylic acid, diacetylene, unsubstituted and substituted
5 acetylene groups, eonophiles, dienophiles and substituted and unsubstituted
6 bicyclo[4.2.0]octa-1,3,5-trienyl groups.
- 1 36. The method of Claim 1 wherein the crosslinked particles are randomly formed.
- 1 37. The method of Claim 1 wherein the polymer molecules further comprise a
2 chemical moiety.
- 1 38. The method of Claim 37 wherein the chemical moiety is a pharmaceutical agent,
2 catalyst, functional group, surfactant, sensor group or photoresponsive unit.
- 1 39. The method of Claim 1 wherein (b) is conducted in the presence of a chemical
2 moiety whereby the chemical moiety is incorporated into the crosslinked particle.
- 1 40. The method of Claim 39 wherein the crosslinked particle has at least one
2 functional group on its backbone and wherein the chemical moiety is attached to
3 the crosslinked particle at said functional group.
- 1 41. The method of Claim 40 wherein the chemical moiety is a pharmaceutical agent,

- 2 catalyst, functional group, surfactant, sensor group or photoresponsive unit.
- 1 42. The method of Claim 1, which further comprises incorporating the crosslinked
2 particles into a matrix.
- 1 43. The method of Claim 42 wherein the decomposition temperature of the
2 crosslinked particles is less than the decomposition temperature of the matrix, and
3 the method further comprises heating the matrix to the decomposition temperature
4 of the crosslinked particles, whereby the crosslinked particles decompose to
5 create a porous matrix.
- 1 44. A method for preparing crosslinked particles, comprising:
2 (a) providing synthetic polymer molecules having a plurality of
3 crosslinkable groups that are inert until activated, but which when activated
4 undergo an irreversible intramolecular crosslinking reaction; and
5 (b) activating the crosslinkable groups under conditions effective to
6 promote said intramolecular crosslinking reaction, such that crosslinked particles
7 are formed; and wherein the conditions in (b) are effective to substantially prevent
8 intermolecular crosslinking between the polymer molecules, such that (b) results
9 in formation of a single crosslinked particle from a single corresponding polymer
10 molecule.
- 1 45. The method of Claim 44 wherein less than 10% of the polymer molecules
2 participate in intermolecular crosslinking.
- 1 46. The method of Claim 45 wherein less than 5% of the polymer molecules
2 participate in intermolecular crosslinking.
- 1 47. The method of Claim 44 wherein the crosslinkable groups are thermally
2 activatable; photolytically activatable; activatable with ultraviolet radiation,
3 ionizing radiation, or electron beam radiation; or activatable by a chemical
4 activating agent.
- 1 48. The method of Claim 44 wherein the polymer molecules have a backbone
2 comprised of monomer units selected from the group consisting of ethylenically
3 unsaturated polymerizable monomers, nitrogenous polymers, olefins,

4 condensation monomers, ring-opening monomers, esters, sulfones, lactides,
5 lactones, carbonates, imides, arylenes, amides, propylene, ethers, urethanes, vinyl
6 and vinyl derivatives, and organic polysilicas.

1 49. The method of Claim 44 wherein the crosslinkable groups are selected from the
2 group consisting of acryloyl, lower alkyl-substituted acryloyl, vinyl, substituted
3 vinyl, cyclic ether, cyclic ester, activated ester, cycloalkenyl, acid halide, amino,
4 alcohol, phenol, carboxylic acid, diacetylene, unsubstituted and substituted
5 acetylene groups, eonophiles, dienophiles and substituted and unsubstituted
6 bicyclo[4.2.0]octa-1,3,5-trienyl groups.

1 50. The method of Claim 44 wherein the crosslinked particles are randomly formed.

1 51. The method of Claim 44 which further comprises incorporating the crosslinked
2 particles into a matrix.

1 52. The method of Claim 51 wherein the decomposition temperature of the
2 crosslinked particles is less than the decomposition temperature of the matrix, and
3 the method further comprises heating the matrix to the decomposition temperature
4 of the crosslinked particles, whereby the crosslinked particles decompose to
5 create a porous matrix.

1 53. A method for preparing crosslinked particles in a solvent, comprising:

2 (a) providing synthetic polymer molecules having a plurality of
3 crosslinkable groups that are inert until activated, but which when activated
4 undergo an irreversible intramolecular crosslinking reaction to form a crosslinked
5 particle;

6 (b) activating the crosslinkable groups; and

7 (c) adding the synthetic polymer molecules to a solvent under
8 conditions effective to allow said irreversible intramolecular crosslinking reaction
9 to take place while substantially preventing intermolecular reaction, resulting in
10 formation of a single crosslinked particle from a corresponding polymer molecule
11 in said solvent.

1 54. The method of Claim 53 wherein (b) is carried out prior to (c).

- 1 55. The method of Claim 53 wherein (b) is carried out during or subsequent to (c).
- 1 56. The method of Claim 53 comprising repeating (a), (b) and (c) without diluting the
2 solvent or removing crosslinked particles therefrom.
- 1 57. The method of Claim 53 wherein in (a), the synthetic polymer molecules are
2 provided in solution.
- 1 58. The method of Claim 57 wherein the conditions comprise providing the solution
2 at a sufficiently dilute concentration so as to substantially prevent intermolecular
3 reactions following activation of the crosslinking groups.
- 1 59. The method of Claim 53 wherein the conditions comprise adding the synthetic
2 polymer molecules to the solvent slowly so as to substantially prevent
3 intermolecular crosslinking between the polymer molecules relative to the rate at
4 which the intramolecular crosslinking reaction occurs.
- 1 60. The method of Claim 53 wherein the conditions comprise adding the solution of
2 the synthetic polymer molecules to the solvent slowly so as to substantially
3 prevent intermolecular crosslinking between the polymer molecules.
- 1 61. The method of Claim 53 wherein the solvent is selected from the group consisting
2 of benzyl ether; N-cyclohexylpyrrolidinone; N-methylpyrrolidone;
3 dimethylacetamide; dimethylphenyl urea; N,N-dimethyltrimethylene urea; butyl
4 acetate; 2-ethoxyethanol; cyclopentanone; cyclohexanone; γ -butyrolactone;
5 lactate esters; ethoxyethylpropionate; alkylene glycol alkyl ether esters; alkylene
6 glycol alkyl ethers; alkylene glycol monoalkyl esters; butyl acetate; 2-
7 ethoxyethanol; ethyl 3-ethoxypropionate; polyethylene glycols and alkyl and aryl
8 derivatives; diphenyl ether; diphenyl sulfone; ethylene carbonate; and mixtures
9 thereof.
- 1 62. The method of Claim 53 wherein the crosslinkable groups are thermally
2 activatable, and the solvent is at a temperature sufficiently high to activate the
3 crosslinkable groups.
- 1 63. The method of Claim 53 which further comprises incorporating the crosslinked
2 particles into a matrix.

1 64. The method of Claim 63 wherein the decomposition temperature of the
2 crosslinked particles is less than the decomposition temperature of the matrix, and
3 the method further comprises heating the matrix to the decomposition temperature
4 of the crosslinked particles, whereby the crosslinked particles decompose to
5 create a porous matrix.